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NOVEL STACKED ARRAY ANTENNA FOR THZ APPLICATION BAND

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ABSTRACT

Nowadays, wireless space communication demands high data rate for communication. The improvement in the bandwidth gives high data rate. THz spectrum is the frequency range of 300GHz to 30THz, in this spectrum the problems of spectrum scarcity and limited bandwidth can be solved. As the Terahertz waves are atmosphere free, hence are good for space communication. With this high gain terahertz antenna it is possible to reduce free space path loss. This proposed work presents a novel, stacked 24-elements array of antenna at 515GHz for Terahertz application band. The antenna is designed on a thin substrate having lower substrate height is 0.2mm with slotted rectangular antenna having conical vias from this layer to ground. While the stacked antenna having substrate height of 0.2mm above the lower layer; with dielectric constant of Ɛr = 3.8. This Terahertz antenna design provides a 11.5 dBi gain and 12.6 dBi directivity . The proposed antenna consists of 24 elements, where these are connected 4 X 6 excites with coplanar waveguide (CPW) feed. This feeding technique gives a good impedance matching at inputs of the radiating elements. The antenna presents a wide bandwidth of 34 GHz and satisfies all performance parameters. It has return loss of -22.5 dB at the resonance frequency of 515GHz (S11< -10dB). The antenna is low cost, less weight and low profile with radiation efficiency of 100%. The antenna is designed, analyzed and optimized on IE3D Zeland software version 15.30

KEYWORDS: ***THz Spectrum, Wireless Space Communication, Array Antenna, Wide Bandwidth & Unallocated Spectrum***

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Original Article

INTRODUCTION

The range of frequency from 300 GHz to 30THz in the electromagnetic spectrum which is in between microwave and infrared band is terahertz(THz)spectrum [1][2]. With naked eye, terahertz radiations are not visible to us. If we compare THz radiations and X-rays then THz are more safety, non-destructive and non-invasive can be seen through dust; clouds etc. [3] so it is a good candidature in adverse weather conditions. THz waves reduces the interference problem, minimizes spectrum scarcity and bandwidth problems in space communication. THz waves are highly directional so provides more secure communication than that of microwaves communication [4] [5]. The size and weight of space vehicles and hence their operational cost can be reduced by use of small size THz antennas in wireless communication. Terahertz spectroscopy has various applications such as identifying tablet coating defects, spectroscopy (chemistry, astronomy), product inspection (industry), weapons concealed under clothing (airports), material characterization (physics), detection of cancer and caries. In the pharmaceutical industries it enables nondestructive, internal, chemical analysis of tablets, capsules and other dosage forms. For space craft interior and for inter orbital data transfer, terahertz wireless communication is more preferable.

10 Gbps per GHz such high data rate can be possible at THz frequencies.

THz technology has number of applications, in security applications, in quality and process controls, environmental monitoring, and medical sciences [6]. THz sensing techniques play an important role in nondestructive evaluation of materials, such as composite materials, plastic-based structures etc. THz waves are sensitive to water, so agricultural and food products can be controlled. Monitoring of water content and damage in the vegetables and fruits can be possible. [7]. THz cameras are effective for giving present quality-control information of products of the industrial and agro-food sectors. Like X-rays THz waves are not always allow harmful radiation. THz beams are harmless to humans, animals, and food while can easily pass through packing materials. THz spectroscopy is a diagnostics tools for breast cancer, prostate cancer, skin cancer, diabetes detection etc.[8]

The advance technology for security, in the field of military and civil, based on THz detection and can be applied to provide terrorist attack security.

This research paper, presents a novel stacked array antenna with two substrate layers . The array structure is on upper layer having 24-element with CPW feed is used, having substrate height is 0.4mm. This feeding technique gives a good impedance matching at inputs of the radiating elements. While the lower slotted patch is designed on a thin substrate having substrate height is 0.2mm, having dielectric constant of $\varepsilon_r = 3.8$. This stacked antenna array provides larger gain by connecting more number of antenna elements and by increasing number of conical vias from lower patch to ground level. The antenna presents a wide bandwidth of 34GHz and satisfies all performance parameters. It has return loss of -22.5 dB at the resonance frequency of 515GHz (S11< -10dB). The antenna is low cost, less weight and low profile with radiation efficiency of 100%. This proposed work shows, a design of high gain microstrip antenna, for THz band operation. The stacked array antenna design consists of an optimized vias from lower patch to ground, which improves gain and directivity of antenna and useful for wireless space communication. This antenna is designed, analyzed and optimized on IE3D Zeland software version 15.30

The stacked array antenna geometry design is discussed in Sections II. The simulated antenna parameters such as VSWR, return loss etc. of the proposed antenna are described in section III, and section IV presents by a conclusion and discussion of stacked array antenna. The square patch is chosen for this design because of its simplicity and analysis performance.

Space communication using THz waves require an antenna with high gain, high directivity, highly efficient, with wide bandwidth, small size and low cost. Photoconductive antennas can be used for such applications.

STACKED ARRAY ANTENNA CONFIGURATION AND DESIGN

Microstrip antenna with single patch geometry is shown in Figure 1 (a) , a square patch is placed on a dielectric substrate of silicon dioxide for radiating purpose to which antenna elements are mounted on it with a probe for exciting the antenna elements microstripline transmission feeding technique is used [10]. All dimensions of all patches of both layers of stack are shown in Table 1.

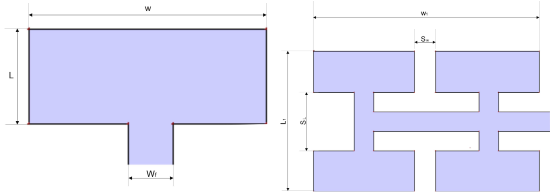

Figure 1: Geometry of (a) Single Patch and (b) 4X1 Array Antenna

The single patch geometry of proposed microstrip antenna having a small size of 22.5µm X 67.5µm is used. The single antenna is not sufficient to satisfy the requirements so array of such four patches are connected to each other to get 4X1 linear array with spacing are 22.5µm and 45µm in horizontal and vertical manner, as shown in Figure 1(b) having the size of 90µm X 158µm. In this proposed system, linearly polarized antenna array with more patches is designed to attain higher bandwidth and gain. Figure 2 shows the antenna elements are etched into the patch and they are fed by an advanced corporate feed network to obtain the required results.

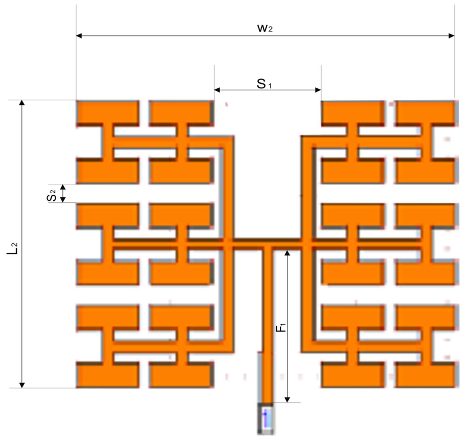

Figure 2: Stacked Array Antenna of Upper Layer Configuration

The lower layer patch having dimensions are 350µm X 450µm, which of slot dimensions are 170µm X 225µm. The open ended via are placed at four corners as shown in Figure 3 having radius of 45µm.

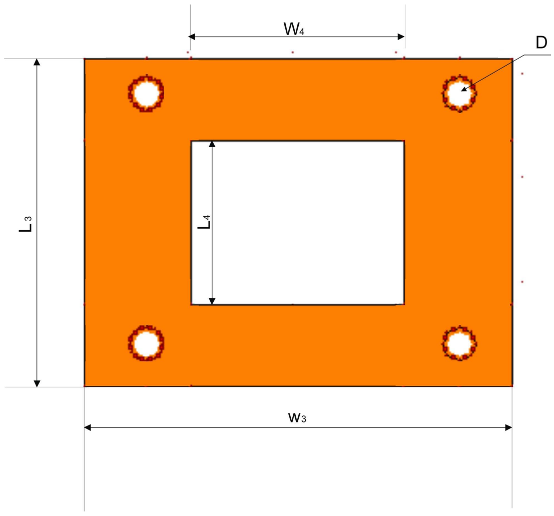

Figure 3: Slotted with Open Ended Vias Patch of Proposed Stacked Antenna Lower Layer (h=0.2mm)

The complete structure of stacked antenna with lower layer at the front side as shown in Figure 4 and upper layer

at the front side as shown in Figure 5. Three dimensional view of the stacked array antenna is as shown in Figure 6, it clears the both layers patch structures and vias from lower layer to ground layer. The proposed antenna consists of an array structure for gain improvement. As well as a slotted patch with stacked structure of an antenna improves bandwidth and open ended vias improves the gain as well as bandwidth parameters.

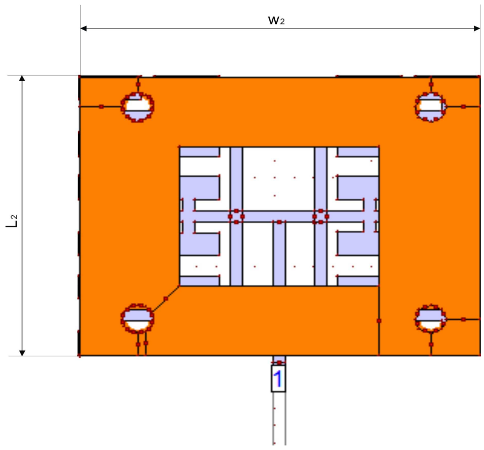

Figure 4: Complete Stacked Antenna with Lower Layer at the Front Side

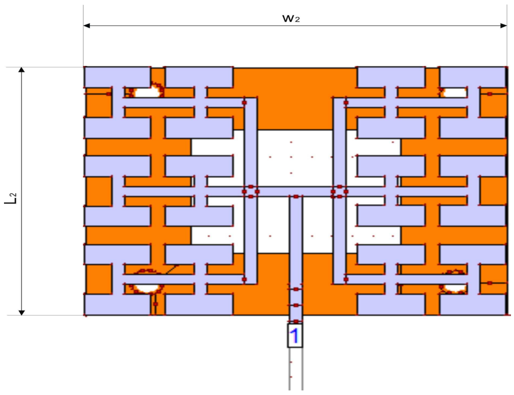

Figure 5: Complete Stacked Proposed Antenna with Upper Layer at the Front Side

Table 1: Patch Dimensions of Proposed Antenna

Sr. No.	Parameter	Dimensions in µm
1	W	67
2	L	22.5
3	W_f	1.8
4	W_1	337
5	L_1	90
6	W_2	450
7	L_2	350
8	W_3	450
9	L_3	350
10	W_4	225
11	L_4	180
12	D	45
13	S_w	22.5
14	S_L	45
15	S_1	135
16	S_2	50
17	F_1	225

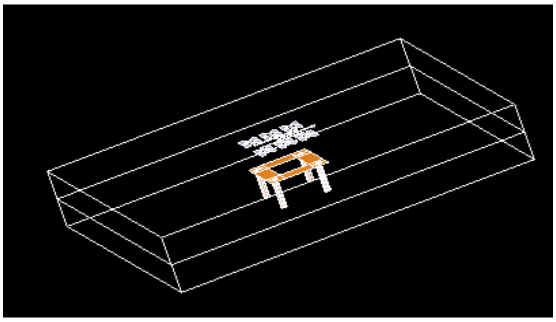

Figure 6: Three Dimensional View of Stacked Array Antenna

The small profile stacked array internal antenna having dimensions are 400µm x 525µm. The top portion of a dielectric substrate having height h=0.2mm and relative permittivity Ɛr=4.4, and loss tangent 0.001 for radiating purpose to which antenna elements are mounted on it with for exciting the antenna elements. The ground plane having dimensions are width 525 µm and length 450µm, with a corporate feed is used for antenna excitation.

The corporate feed widely uses parallel feed configuration. The power is equally dividing at each junction [10]. However for power distribution across the array, different power divider ratios can be assigned. This type of feed demands a long transmission lines between radiating elements and the input port is one of disadvantage, therefore overall efficiency of array may decreased [9] .The corporate feed is being discussed for this 4x6 array of microstrip patch antenna to achieve, higher gain, input impedance and better bandwidth of the antenna array. Because single antenna is not enough to achieve high gain, as it has limited gain.

STACKED ARRAY ANTENNA PERFORMANCE PARAMETERS

This section covers different parametric study of the stacked antenna in the presence of the slotted structure. The simulated return loss is as shown in Figure 7 and Figure 8 shows VSWR of the proposed corporate feed antenna. This antenna gives favorable return loss curve in the range of frequency from 488GHz to 522GHz. The curve has deepness is at frequency 515GHz. The return loss obtained at that frequency is -22.5 dB. The current design attains a bandwidth of 34GHz which correspond to 6.6%. The wider bandwidth is achieved with the help of coplanar waveguide network. In this proposed paper the square patch is chosen because of its simplicity in design and analysis performance. The co-planar waveguide feed network is a six way power divider where 4×6 array ports are placed. The power is split up among all the ports equally with the help of a chambered junction. Once the power moves to the center of the co-planar waveguide line, transition takes place which shows that antenna elements are feed by it and provides the required output such as bandwidth and VSWR efficiency.

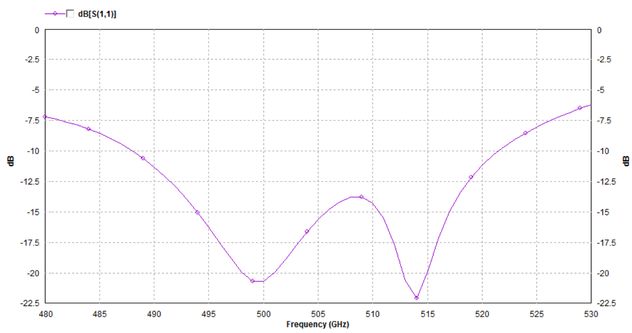

Figure 7: The Return Loss Verses Frequency of Stacked Array Antenna

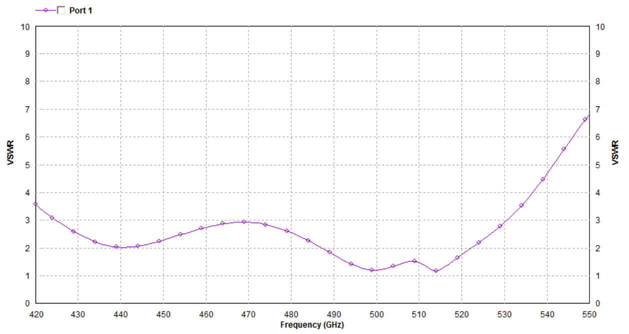

Figure 8: Simulated VSWR Against Frequency of Stacked Array Antenna

VSWR (Voltage Standing Wave Ratio) can be defined as the ratio of maximum to minimum value of voltage. VSWR of 2:1 is used for this design, as impedance matching bandwidth, which is generally acceptable for practical wireless applications as shown in Figure 8. 2D Radiation Pattern at 515GHz is as shown in Figure 9 for stacked array antenna.

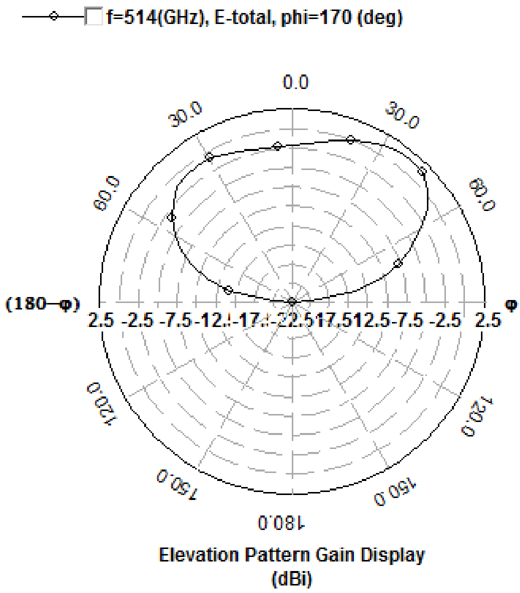

Figure 9: Radiation Pattern of Stacked Array Antenna

The two dimensional radiation pattern of stacked arrays antenna is as shown in Figure 9. By increasing the number of elements in the array indicates the directivity and gain increases, with decrease in the beam width. The 4x6 array has 11.5 dBi as its maximum gain and 12 dBi as its directivity. The requirements of short range indoor wireless application are satisfied by these parameters. This antenna is compact in size, hence can be integrated with the existing MMIC‘s. If further improvement in gain and beam width is needed, then we can go for 4x8 arrays and 4x10 arrays with similar design concepts.

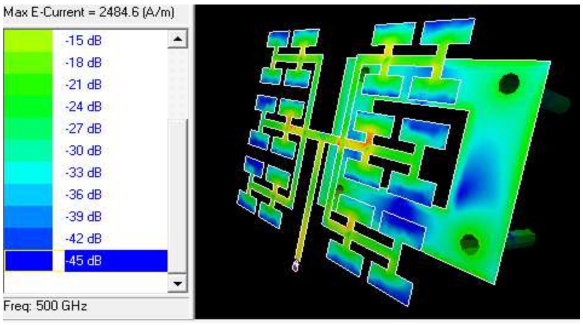

Figure 10: Simulated Current Distribution of Stacked Array Antenna

The surface current distributions on the printed metal portion of the stacked array antenna are as shown in Figure 10. The comparatively strong current distributions are observed on the feeding strip. The proposed stacked array antenna structure is comprised of, the ground plane and radiating strips. The entire antenna configuration acts as an effective radiating system which covers wide bandwidth of 488GHz to 522GHz.

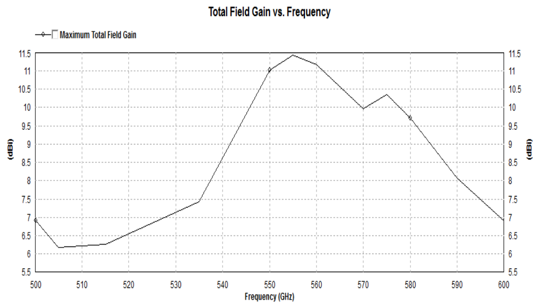

Figure 11: Total Field Gain Verses Frequency for Stacked Array Antenna

The total field gain of this slotted stacked array antenna is about to 11.5 dBi which was very good parameter as shown in Figure 11, while the directivity gain is 12.7dBi as shown in following Figure 12.

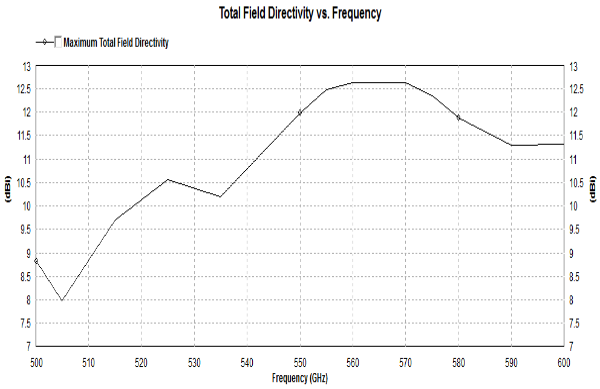

Figure 12: Total Field Directivity Against Frequency for Stacked Array Antenna

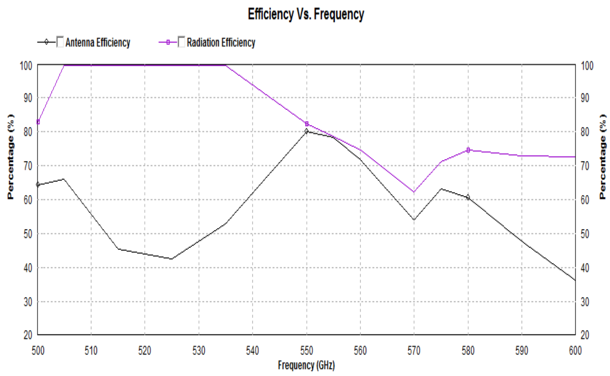

Figure 13: Radiation Efficiency and Antenna Efficiency Verses Frequency of Stacked Array Antenna

The stacked array antenna with the presence of wide bandwidth and excellent radiation efficiency of 100% all over the desired operating range is as shows in Figure 13. The antenna efficiency is also about to 80%. This is the good candidature for universal THz band application for wireless communication systems.

CONCLUSIONS AND DISCUSSIONS

This research work proposed a corporate feed technique used to stacked array antenna design. The antenna parameters, including radiation patterns, return loss, VSWR, radiation efficiency and antenna efficiency are satisfied the proposed antenna for the universal terahertz application band for short-range communication systems. The 80% radiation efficiency was achieved over the desirable operating band, for wireless communication system applications. They achieve higher gain of 11.5dBi and better bandwidth of 19GHz centered at 515 GHz. We observed from the above results that the increase in the number of elements of an array technique and number of vias in the lower layer slotted patch results; increase the impedance bandwidth, gain and directivity of 12.7dBi is obtained. Millimeter wave microstrip antenna is smaller in size and lower in cost. Therefore this antenna can be advised as a good for indoor application and short distant speedy communications at THz.

All simulated results indicate that a high-performance antenna array is obtained by simply using the proposed corporate feed technique. THz short-range wireless communication can provide very high data rates which appears to be one of the possible solution for future high bandwidth demand.

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